Task Force on the Future of American Innovation

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May 10, 2007

Measuring Innovation in the 21st Century
Economy Advisory Committee
Attn: Elizabeth "E.R." Anderson
Economics and Statistics Administration
Department of Commerce
14th and Pennsylvania Avenue, NW
Washington, DC 20230

Dear Members of the Committee:

The Task Force on the Future of American Innovation hereby submits the benchmarks in its report, "Measuring the Moment: Innovation, National Security and Economic Competitiveness," for consideration as measurements of innovation.

Thank you for your consideration.

Sincerely,

Steve Pierson
American Physical Society

**THE TASK FORCE**
**ON THE FUTURE OF AMERICAN INNOVATION**

*Innovation Is America's Heartbeat*

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# MEASURING THE MOMENT:

## Innovation, National Security, and Economic Competitiveness

BENCHMARKS OF OUR INNOVATION FUTURE II

November 2006

**The Task Force on the Future of American Innovation** is a coalition of business, scientific and university organizations that came together in 2004 out of concern that insufficient investment by the federal government in research in the physical sciences and engineering was threatening the nation's global economic leadership and national security in an increasingly competitive world.

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**Acknowledgments**

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# Introduction

"To keep America competitive, one commitment is necessary above all: We must continue to lead the world in human talent and creativity."

*-President George W. Bush, State of the Union Address, January 31, 2006*

In the 20th century, the United States maintained a uniquely durable leadership in the world. Thanks to a powerful combination of robust investment, human ingenuity and a marketplace hospitable to innovation, dynamic advances in American research and technology sparked an explosion of economic growth and enhancements to people's lives that resonated around the world. However, in the 21st century, we confront a time when the ingredients of this leadership are at risk.

Last year, the Task Force on the Future of American Innovation issued *The Knowledge Economy: Is the United States Losing Its Competitive Edge?*[1] Subtitled "Benchmarks of Our Innovation Future," the white paper provided a number of measures to determine whether the United States was in position to maintain its global leadership in research and technology.

The news was mixed. As we wrote at the time, "The United States still leads the world in research and discovery, but our advantage is rapidly eroding, and our global competitors may soon overtake us…It is essential that we act now; otherwise our global leadership will dwindle, and the talent pool required to support our high-tech economy will evaporate…This is not just a question of economic progress. Not only do our economy and quality of life depend critically on a vibrant research and development (R&D) enterprise, but so too do our national and homeland security."

This document updates *The Knowledge Economy*. It provides the latest available information on the benchmarks cited last year, and it establishes new ones as well. It makes clear that the problems we described last year — in areas that include federal support for basic research in the physical sciences and engineering, Ph.D.s in the natural sciences and engineering, students' interest in pursuing science and engineering studies, and the trade balance in high-tech products — have not disappeared. They are long-term trends that the new figures confirm.

1. http://futureofinnovation.org/PDF/Benchmarks.pdf.

This report also makes clear that the economic argument for greater federal investment in basic research is matched by the national security imperative. The United States is investing too little for the new global strategic environment. Research in physics, mathematics, computer sciences and engineering is the basis for military transformation. Moreover, it builds the workforce of citizens needed for classified projects. A robust research portfolio is a necessary part of a national security strategy that relies on knowledge and technology to keep the United States safe in a dangerous world.

America came to lead the global science and technology enterprise because it supported and rewarded research and education in the sciences and engineering in more varied, meaningful ways than any other country. These benchmarks demonstrate the need to renew our commitment to the human talent and creativity that go into scientific research and education and serve vital national interests.

**The Building of a Consensus**

The Task Force's *Benchmarks* report in 2005 helped raise an alarm about the need to invest in this nation's research capabilities and manpower in the physical sciences and technology. While we were in the vanguard, we were far from alone. Between December 2004 and January 2006, a long list of business and academic organizations — including the National Academies of Science, the Council on Competitiveness, the Business Roundtable (joined by the U.S. Chamber of Commerce and numerous other national groups), the Center for Strategic and International Studies, the National Association of Manufacturers, AeA, the Telecommunications Industry Association, the Electronic Industries Alliance, the Association of American Universities, the Council of Graduate Schools, the Business-Higher Education Forum, the Defense Science Board, the National Research Council and the National Intelligence Council — issued reports[2] making separate but related and carefully documented cases that the nation needed to take these steps:

- Greatly strengthen the nation's investment in basic research in the physical sciences and engineering, most of which takes place at public and private research universities;
- Improve the capacity of our system of education, from kindergarten to graduate school, to produce more and better scientists and engineers; and
- Continue to attract and retain the best scientific and engineering talent from abroad.

This outpouring of reports from a broad range of interests has shaped the public debate. Certainly the American people are convinced. A strong majority believes the country needs to invest more in basic research. For example, a national survey conducted by Public Opinion Strategies and commissioned by this

2 See: http://www.aau.edu/research/CompetitivenessDOCS.pdf.

task force showed that 70 percent of the public supports increasing federal funding by 10 percent a year for the next seven years for university research in science and engineering. The same survey shows that 49 percent of the electorate believes America's ability to compete economically in the world has grown worse over the past few years. This number is up from 38 percent in 1991.

**Policymakers Respond**

Policymakers may be at the point of acting on this consensus. In the nation's capital, comprehensive legislation to encourage research and improve science and math education has been introduced by Republicans and Democrats in the Senate and House. And President Bush, specifically citing the National Academies report, has proposed the American Competitiveness Initiative (ACI)[3], which would invest significant new resources in the nation's innovative capacity. Among other steps, the ACI proposes to:

- Double, over 10 years, the aggregate funding for basic research at the National Science Foundation, the Department of Energy's Office of Science and the National Institute of Standards and Technology within the Department of Commerce;
- Make permanent the research and development tax credit;
- Strengthen K-12 science and math education; and
- Increase the nation's ability to compete for and retain the best talent from around the world.

We are gratified that the President and many other national leaders agree that a robust national investment in research in the physical sciences and engineering is critical to U.S. global economic leadership in the 21st century. This update to Benchmarks details the worldwide trends that warrant support for the American Competitiveness Initiative and similar congressional proposals.

**Basic Research — Key to Innovation, Competitiveness, Prosperity**

Basic research in the physical sciences and engineering represents only seven percent of the federal R&D portfolio, but it has, arguably, the greatest economic impact.

Economists attribute a significant portion of the extraordinary boom in productivity during the 1990's to technological innovation. Citing innovation as the reason for significant gains in productivity growth since 1995, then Federal Reserve Board Chairman Alan Greenspan told Congress: "Had the innovations of recent decades, especially in information technologies, not come to fruition, productivity growth would have continued to languish at the rate of the preceding twenty years."[4] The energy for this tidal wave of

3. http://www.ostp.gov/html/ACIBooklet.pdf.

4. Alan Greenspan, Testimony Before the Senate Budget Committee, Jan. 25, 2001. see: http://www.senate.gov/~budget/republican/about/hearing2001/greenspan.htm.

innovation came from basic research, much of which was performed years earlier on university campuses and elsewhere.

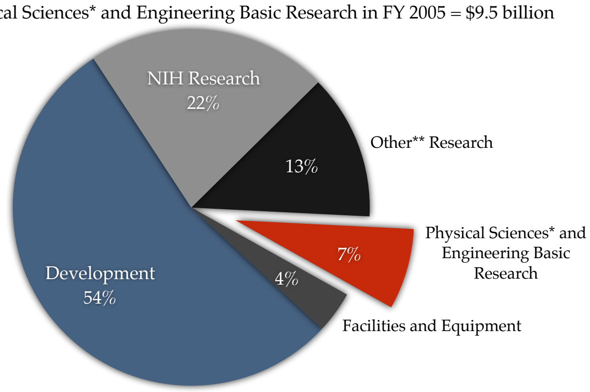
The connection between basic research and the economy is straightforward. Basic research produces the discoveries and ideas that form the basis of products that transform and strengthen our economy. Consider the transistor, the computer, the Internet, communications technologies and the myriad laser applications. Each of these was built upon a foundation laid by basic research by scientists and engineers. Most Americans carrying an iPod today have no idea that the MP3 technologies and other critical elements of this extraordinary product are based upon federally supported research.

Entire major industries have been created or revolutionized by federally supported basic research. For example, federally supported research in fiber optics and lasers helped create the telecommunications revolution that turned the telecommunications and information technology industries into behemoths of the American economy. And the biotechnology industry is a multibillion-dollar end-product of federally supported basic research. It is no wonder that economist Edwin Mansfield calculated as much as a 40 percent return for the federal investment in basic university-based research.[5]

Funding for Physical Sciences and Engineering Basic Research a Small Part of Federal R&D Portfolio

Total Federal R&D Portfolio in FY 2005 = $130 billion

Total Physical Sciences* and Engineering Basic Research in FY 2005 = $9.5 billion




* Physical Sciences includes Physics, Chemistry, Astronomy and the NSF definitions of Environmental Science, Mathematics and Computer Science.
** Other research is comprised mainly on non-NIH research.
Source: *Fiscal Year 2007 Analytical Perspectives*. Budget of the U.S. Government.
Compiled by the APS Physics Washington Office.

Moreover, advances in one field of science are critical to advancing others. For example, long-term breakthroughs in biological and life sciences rely on advances in medical diagnostics that are the result of research in the physical sciences and engineering. Citing magnetic resonance imaging (MRI), Harold Varmus, former director of the National Institutes of Health (NIH), remarked, “Medical advances may seem

5 Edwin Mansfield, "Academic Research and Industrial Innovation: a further note," *Research Policy* 21 No. 3 (June 1992): 295-296; See also: Edwin Mansfield, "Academic research and industrial innovation: an update of empirical findings," *Research Policy* 26 No. 7-8 (April 1998): 773-776; Congressional Budget Office, "CBO Staff Memorandum: A Review of Edwin Mansfield's Estimate of the Rate of Return From Academic Research and Its Relevance to the Federal Budget Process," US Government Printing Office, April 1993.

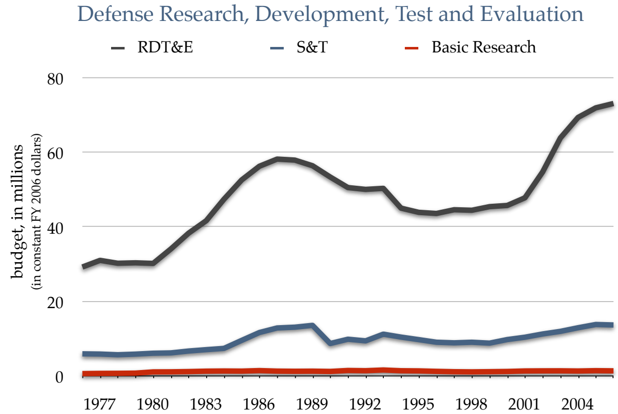
like wizardry. But pull back the curtain, and sitting at the lever is a high-energy physicist, a combinatorial chemist, or an engineer."[6] For this reason is important that we sustain growth in all fields of science.

**Basic Research — The National Security Imperative**

Breakthroughs in basic science — such as those in radar, lasers, optics and microelectronics — have played a major role in establishing and maintaining our military superiority. To help American troops retain their advantage on the battlefield in the future, it is critical that new investments be made today in areas such as energy storage, materials research, nanotechnology and high-performance computing. If we do not make these investments, U.S. forces will increasingly depend on technology imported from other nations.

While U.S. spending on military R&D is at a record high, recent increases have been devoted to applying existing ideas to the production of new weapons and equipment. We have been underinvesting in the basic research needed for the next generation of military technology. Since the end of the Cold War, the share of the Department of Defense (DOD) investment in science and technology[7] devoted to basic research has declined significantly, from 20 percent in 1980 to less than 12 percent in 2005. The accompanying chart shows that over the past five years alone, overall Research, Development, Testing and Evaluation (RDT&E) has grown by over one-third, yet investment in basic research has remained flat.

Defense Basic Research Has Remained Flat Despite Overall Growth in Defense Research, Development, Test and Evaluation




Source: American Association for the Advancement of Science, 2006

The National Research Council and the Defense Sciences Board (DSB) have both sounded alarms concerning our investment in basic research in fields critical to our national defense, such as high performance

6. Harold Varmus "Squeeze On Science," *The Washington Post*; Wednesday, October 4, 2000, p. A33.

7 "Science and Technology" is defined as DOD categories 6.1 (Basic), 6.2 (Applied) and 6.3 (Advanced Technology Development). "Research, Development, Test and Evaluation" includes 6.1, 6.2, and 6.3, plus 6.4 (Demonstration and Evaluation), 6.5 (Engineering Manufacturing Development), 6.6 (Management Support), and 6.7 (Operational Systems Development).

computing and microchips and semiconductors.[8] The point they make is clear: If the nation does not re-invigorate its investment in the creation of new fundamental knowledge for national security, the United States will not have the most advanced weapons systems and military technologies.

The DSB has also expressed concern that DOD and defense-related industries are having "…difficulty attracting and retaining the best and brightest students to the science and engineering disciplines relevant to maintaining current and future strategic strike capabilities."[9] The DSB notes that the aerospace and defense industries are experiencing increasing difficulty in finding U.S. citizen scientists qualified to work on classified research projects. Unlike other sectors, the defense and aerospace industrial sector and the national security and intelligence communities need U.S. citizens who can obtain security clearances, so they are in most instances unable to rely on foreign-born talent. This is one reason the United States must grow its own domestic pool of science and engineering talent. To accomplish this, we must ensure that U.S. scientists and students in fields critical to national defense are well supported and given opportunities to work on important and challenging defense-related research projects.

**U.S. Leadership Faces Increasing Challenge**

The benchmarks presented in this paper show that countries such as China and India are increasing their innovative capabilities, from research investment and science and engineering (S&E) degree production to high-tech products, at a time when, using the same measures, the United States appears to be slowing. They demonstrate that to stay ahead we need to reinvigorate the foundation of our innovation economy.

As the National Academies report, *Rising Above the Gathering Storm*, states, "The scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength." We can quibble about specific statistics and metrics used to measure current trends, but the big picture is increasingly clear. If we wait to be absolutely sure these trends are what they appear to be, it will become ever more difficult and expensive to recover.

We believe our nation's greatness lies in the creativity, entrepreneurship and collaborative spirit of its people. These qualities, as well as the attraction they hold for the best talent from overseas, have made our nation the unquestioned global leader in science and research. This report shows the threat to that leadership. It is abundantly clear that the same qualities that established our leadership can help us over-

8. Assessment of Department of Defense Basic Research, National Research Council, January 2005, http://books.nap.edu/catalog/11177.html; Report of the Defense Science Board Task Force on High Performance Microchip Supply, Office of the Undersecretary of Defense for Acquisition, Technology and Logistics, U.S. Department of Defense, February 2005, http://www.acq.osd.mil/dsb/reports.htm; and Report of the Joint U.S. Defense Science Board and UK Defense Scientific Advisory Council Task Force on Defense Critical Technologies, Office of the Undersecretary of Defense for Acquisition, Technology and Logistics, U.S. Department of Defense, March 2006, http://www.acq.osd.mil/dsb/reports/2006-03-Defense_Critical_Technologies.pdf.

9. Report of the Defense Science Board Task Force on Future Strategic Strike Skills, Office of the Undersecretary of Defense for Acquisition, Technology and Logistics, U.S. Department of Defense, March 2006, http://www.acq.osd.mil/dsb/reports/2006-03-Skills_Report.pdf.

come that threat. The initial response from our nation's leaders suggests they take these threats to American leadership seriously and that they intend to continue to make the necessary investments to keep the U.S. ahead. We certainly hope so.

# Research Investment

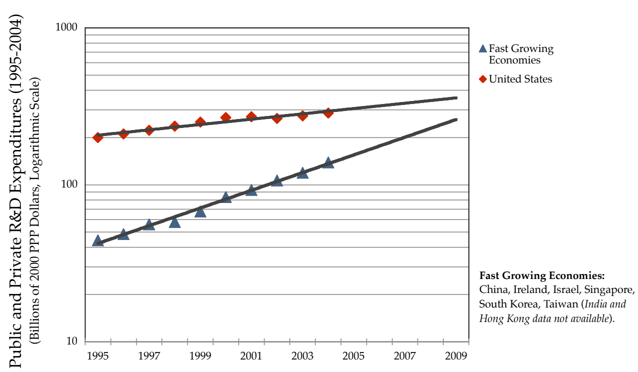
Research investment yields advances in knowledge and technologies that provide jobs, improve lives, and safeguard a better future. Our commitment to research — the front end of a vital innovation-based economy and national security strategy — is flagging. The longer we put off renewing this commitment, the harder it will be to maintain leadership in international science and technology. These benchmarks make clear our waning commitment.

**What is basic research?**

Basic research is the prerequisite of applied research and development. It is conducted in an effort to achieve fundamental knowledge that frequently yields specific applications, including significant technological or health advances, or even whole new industries. Its results can be unpredictable, but as former House Speaker Newt Gingrich has written, "many of the really big changes that will transform our lives will come from unpredictable [research] breakthroughs."

- **Fastest-growing economies continue to increase their R&D investments rapidly, nearly five times the rate of the United States:** The countries of China, Ireland, Israel, Singapore, South Korea and Taiwan collectively increased their R&D investments by 214 percent between 1995 and 2004. The United States in that period increased its total R&D investments by 43 percent. China, from 1991 to 2004, increased its investment by a staggering 516 percent.[10] (In contrast to the increase in total public and private R&D investments seen here, the U.S. federal investment in the physical sciences and engineering research has been flat for much of the last two decades.)[11] Although they are starting from a very low base, these countries will substantially narrow the gap if they can continue this rate of investment.

Emerging Economies Rapidly Increasing R&D Investments




Source: OECD Main Science and Technology Indicators, November 2005. Compiled by the APS Washington Office.

- **United States falls in rankings of percentage of GDP spent on R&D:** The United States was passed by three countries between 1991 and 2004 in the percentage of GDP spent on R&D, dropping it from second behind Japan to fifth behind Israel, Finland, South Korea and Japan. The U.S. percentage has remained at 2.4-2.7 percent since 1991. Taiwan seems poised to sur-

10. OECD Main Science and Technology Indicators, May 2006, http://www.sourceoecd.org.

11. See graph on p. 28.

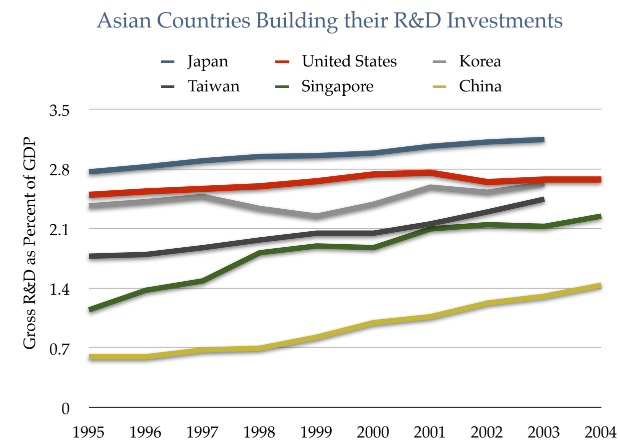
pass the United States in this category in the next several years. China doubled its percentage from 0.6 percent in 1995 to 1.23 percent in 2004.[12]

- **U.S. physical sciences and engineering research budgets significantly lag economic growth:** As a share of GDP, the U.S. federal investment in both physical sciences and engineering research has dropped by half since 1970. In inflation-adjusted dollars, federal funding for physical sciences research has been flat for two decades, as seen in the "Funding by Discipline" chart on p. 28. Support for engineering research is similar.

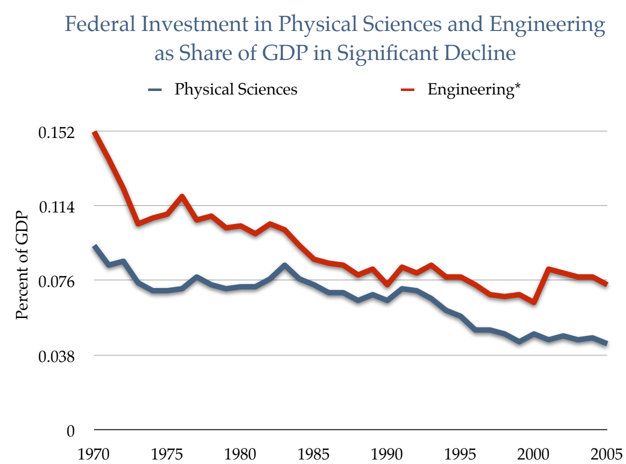
**Why doesn't industry fund more basic research?**

Why doesn't industry fund more basic research? Of the more than $330 billion spent on research and development (R&D) in the United States, more than $200 billion is funded by industry to develop or improve products, or enhance industrial processes. Yet only 5 percent of U.S. industry's R&D spending goes to basic research.[i] The rest is applied research and development. The reason is that it is considerably easier for nations to capture the benefit of their investment in basic research than it is for companies. Basic research is unpredictable, and turning such research into a marketable product can take a decade or longer. Financial markets and international competition make it hard for companies to invest in research that does not show quick results. In essence, basic research is a public good that, like national defense or the highway system, single companies cannot afford. But if government invests in it, all companies and individuals benefit. The market underinvests in basic research; government cannot afford to.

*i.* National Science Foundation, *Science and Engineering Indicators, 2006.*




Source: OECD Main Science and Technology Indicators. Compiled by the APS Physics Washington Office.




*The 2001 jump in engineering is due to reclassification of funding and is therefore artificial.
Source: American Association for the Advancement of Science. http://www.aaas.org/spp/rd/guidisc.htm.
Compiled by the APS Washington Office.

12. *Main Science and Technology Indicators*, Organisation for Economic Co-operation and Development (OECD), multiple issues.

## TRENDS TO WATCH

**China redoubles its scientific commitment with an eye toward innovation:** In an effort to place more emphasis on innovation and breakthroughs in science and technology, China has unveiled a blueprint that will guide scientific research for the next 15 years and that will boost spending on R&D from $26 billion in 2004 to $110 billion in 2020.[ii] According to China's Vice Minister of Science and Technology, Cheng Jinpei, the plan is part of China's strategy to become a world leader in science and technology.[iii] Compared to the United States, China is spending a greater percentage of its R&D investment in the hard science areas that underpin modern defense and commercial activities, whereas the United States is investing more heavily in the medical, psychological and social problem (*e.g.*, drug use) science areas that underpin improvement of individual health and comfort.[iv]

*ii.* "Innovation Craze Hits China," *Science Magazine*, Feb. 17, 2006, p. 931.

*iii.* "China Urges More Efforts on Innovation in Science Work," *China View* (www.chinaview.cn) Dec 12, 2005.

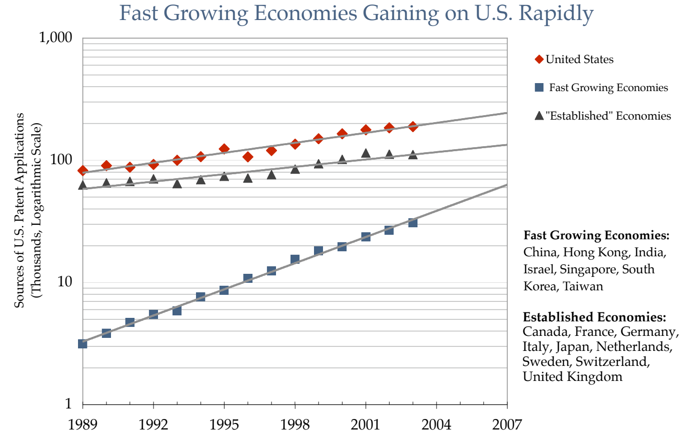
*iv.* "The Structure and Infrastructure of Chinese Science and Technology," Office of Naval Research, 2006.

# Knowledge Creation

Innovators transform new knowledge into products and services. The United States has led the world in innovation and in the creation of knowledge that fuels this progress. Two benchmarks of knowledge creation, journal articles and patents, reveal that change around the world is eroding traditional U.S. leadership in these areas. Other countries are rapidly enlarging their stock of intellectual property assets and are expanding the boundaries of learning and discovery across all fields of science and engineering. Growth in patent applications around the world shows that these countries are also enhancing their abilities to put newly created knowledge to viable commercial uses.

- **Fast-growing economies continue rapid growth in U.S. patent applications:** The collection of fast-growing economies reported in the first Benchmarks report continued their strong growth in applications with a 13.8 percent increase from 2001 to 2002 and a 14.9 percent increase from 2002 to 2003, though slightly below the annual average increase for the 10-year period ending in 2003 of 17.2 percent. The United States, which has maintained a roughly constant 55 percent of total U.S. patent applications in that time, averaged 7.0 percent annual increases but only 3.8 percent for 2002 and 2.5 percent for 2003.[13] The preliminary fiscal year 2005 data confirm these trends.[14]

U.S. Patent Applications:
Fast Growing Economies Gaining on U.S. Rapidly




Source: National Science Foundation, *Science and Engineering Indicators 2006*. Compiled by APS Washington Office.

- **South Korea continues strong U.S. patent application growth:** Among the fast-growing economies, South Korea is particularly notable. Over a ten-year period through 2003, South Korea has averaged 22 percent annual increases in its U.S. patent applications. With a 31 percent jump in 2003, it filed 10,411 patent applications, up from 1,624 in 1993. In that same time, it jumped in the country rankings from 10 to 5. Taiwan, with 17 percent average growth over that ten-year period, went from 7th to 4th. China and India experienced average annual increases of 27 percent and 37 percent over 10 years, respectively, but started with much smaller numbers, being ranked 17th and 18th in the

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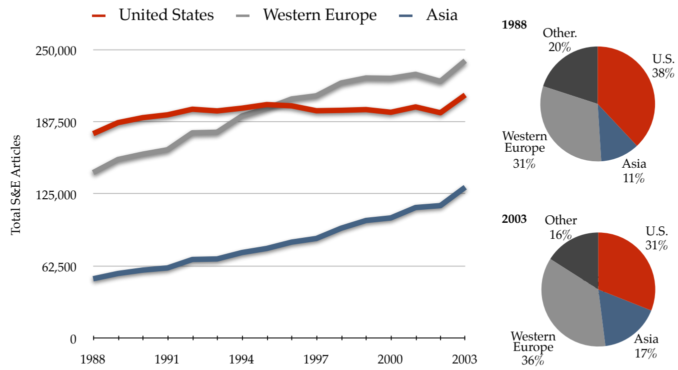
13. *2006 Science and Engineering Indicators*, National Science Foundation.

14. "Performance and Accountability Report Fiscal Year 2005," U.S. Patent and Trademark Office, Tables 6.4.7 and 6.4.9, http://www.uspto.gov/web/offices/com/annual/2005/0604_workloadtables.html.

country rankings. The United States, Japan and Germany remained ranked 1st, 2nd and 3rd over all of the 10 years.[15]

- **U.S. share of S&E publications continues to shrink**: In the first Benchmarks report, we reported that the U.S. share of worldwide science had shrunk from 38 percent in 1988 to 31 percent in 2001. The 2003 data reveal that the number continued to decline, due largely to increased Asian output.

S&E Publications: U.S. Already Passed by Western Europe, Asia Rapidly Closing




Source: 2006 NSF Science and Engineering Indicators.
Compiled by the APS Washington Office

## TRENDS TO WATCH

**China's output of research articles expands dramatically:** In terms of sheer numbers of research articles, especially in critical technologies (*e.g.*, nanotechnology, energetic materials), China is among the leaders. In terms of citation impact, it was higher than India in all major categories (*e.g.*, physical, environmental, materials and life sciences).[v]

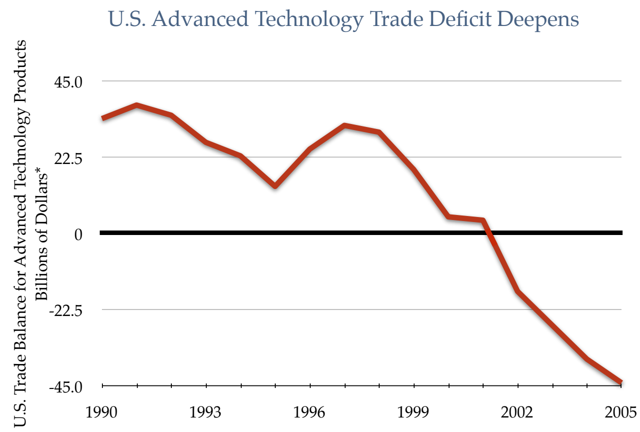
*v*. "The Structure and Infrastructure of Chinese Science and Technology", Office of Naval Research, 2006.

15. 2006 *Science and Engineering Indicators,* National Science Foundation.

# High-Tech Economy Benchmarks

Leadership in the high-tech economy is the bedrock of the U.S. economy and its competitiveness. In 2005, U.S. high-tech industries employed 5.6 million people, paying salaries 85 percent greater than average private sector jobs.[16] And it remains the largest exporter among all industry sectors, accounting for 22 percent of U.S. exports.[17] But a healthy high-tech economy requires a robust science and engineering enterprise because of these industries' reliance on new ideas and the people who make them.

- **High-Tech trade deficit continues to widen:** The annual trade deficit for advanced technology products grew in 2005, for the third straight year. The deficit of $44 billion for 2005 is now larger than the largest surplus of the last 15 years. The 2005 value marks the fourth straight year that the United States has imported more high-tech products than it has exported.[18] While many of those imports come from countries in which U.S. companies own manufacturing facilities, this shift in manufacturing helps build techno-




Source: U.S. Census Bureau Foreign Trade Statistics, *U.S. International Trade in Goods and Services*.
Compiled by the APS Washington Office.
* Constant Chain-weighted 2000 Dollars

**QUOTED**

"Civilization is on the brink of a new industrial world order. The big winners in the increasingly fierce global scramble for supremacy will not be those who simply make commodities faster and cheaper than the competition. They will be those who develop talent, techniques, and tools so advanced that there is no competition. That means securing unquestioned superiority in nanotechnology, biotechnology, and information science and engineering. And it means upgrading and protecting the investments that have given us our present national stature and unsurpassed standard of living."

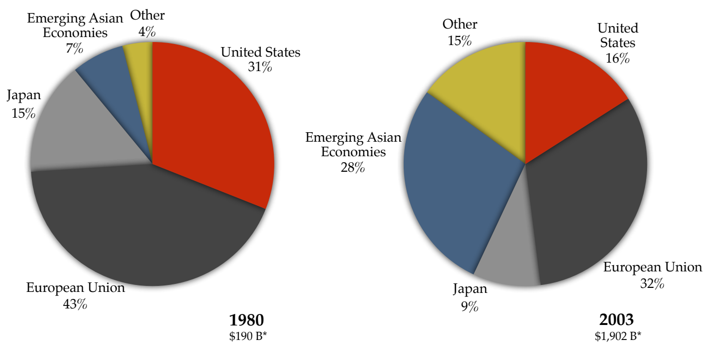
- President's Council of Advisors for Science and Technology, *Sustaining the Nation's Innovation Ecosystems: Information Technology Manufacturing and Competitiveness*, January 2004. http://www.ostp.gov/PCAST/FINALPCASTITManuf%20ReportPackage.pdf

16. "Cyberstates 2006: A complete state-by-state overview of the high-technology industry." American Electronics Association, 2006.

17. "The Information Technology 100," *BusinessWeek*, 21 June 2004. http://www.businessweek.com/pdfs/2004/0425_it100.pdf.

18. U.S. Census Bureau Foreign Trade Statistics, *U.S. International Trade in Goods and Services*, June 2006. http://www.census.gov/foreign-trade/www/press.html.

High-Tech Industry Exports: U.S. Losing World Share




**Emerging Asian Economies:** China, South Korea, Taiwan, Singapore, Hong Kong, India

* 1997 U.S. Dollars. High-tech includes Aircraft, Pharmaceuticals, Office and computing machinery, Communication equipment, Medical, precision, and optical instruments, Communication equipment, Medical, precision, and optical instruments.
Source: National Science Foundation, *Science and Engineering Indicators 2006*
Compiled by Association of American Universities and APS Washington Office.

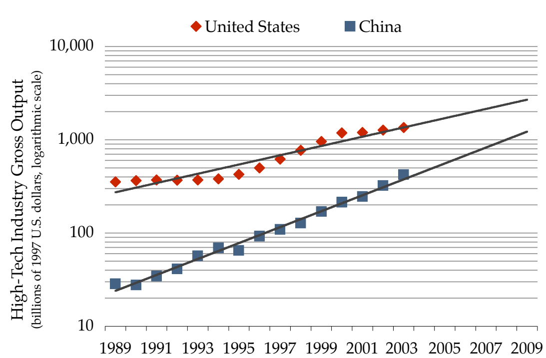
logical capabilities in those countries.

• **U.S. lags most OECD countries in high-tech export/import ratio:** Between 1990 and 2002, only one of 24 OECD countries saw its ratio of high-tech exports to high-tech imports drop more precipitously than the United States. The U.S. ratio dropped from $1.23 of exports for every dollar of imports to only 86 cents of exports for every dollar of imports. In 2002, the United States ranked 16th of 29 OECD countries.[19]

• **U.S. share of high-tech exports continues to slide, though value rises:** The U.S. share of high-tech exports shrank to 16 percent in 2003, from 30 percent in 1980, as the share for emerging Asian economies expanded dramatically. The overall value of the exports, on the other hand, continues to grow — from $57 billion in 1980 to $304 billion in 2003 (1997 U.S. dollars).[20]

• **More R&D facilities are being located abroad:** In a large survey of several industries in the United States and Europe, 48 of 235 recent or planned R&D facilities were located in the United States, 55 in China and 18 in India.[21] A report by Booz Allen Hamilton and INSEAD published May 15, 2006, paints a starker picture. The report found that of 186 companies in 19 nations that together account for 20 percent of global corporate R&D expendi-

China Gaining Rapidly on U.S. in High-Tech Industry Output




Source: National Science Foundation, Science and Engineering Indicators 2006. Appendix Table 6-2. Compiled by the APS Washington Office.

19. "The OECD STAN Indicators database," OECD http://www.sourceoecd.org.

20. *2006 Science and Engineering Indicators,* National Science Foundation, Appendix table 6-4.

21. J. Thursby & M. Thursby, "Factors in International R&D Location and Intellectual Property Protection," pre-published version, 2006.

tures, "77 percent of the new R&D sites planned over the next three years will be located in either China or India."[22]

- **The impact of China and India on global R&D is significant and growing rapidly:** In 1990, these two countries accounted for 3.4 percent of foreign R&D sites, a figure that increased to 13.9 percent by 2004. "By the end of 2007, China and India will account for 31 percent of global R&D staff, up from 19 percent in 2004."[23]

- **R&D facilities follow the talent:** According to a 2006 Kauffman Foundation report, "it is intellectual capital and university collaboration, not just lower costs, that primarily attract companies to locate R&D activities in locations away from their home country." Other factors identified by report authors Marie Thursby and Jerry Thursby include intellectual property, regulatory, tax and legal issues.[24]

    - *Case in point:* China's National Research Center for Science and Technology for Development states that there are more than "600 R&D laboratories affiliated with non-Chinese multinationals in China."[25]

22. "Innovation: Is Global the Way Forward?" Booz-Allen Hamilton and INSEAD, 2006. http://www.boozallen.com/media/file/Innovation_Is_Global_The_Way_Forward_v2.pdf, as reported in SSTI Weekly Digest, May 22, 2006, http://www.ssti.org/Digest/2006/052206.htm.

23. *Ibid.*

24. "New Kauffman Foundation Study Identifies Key Factors Driving Offshoring of Corporate R&D," Kauffman Foundation Press Release, Feb. 16 2006, http://www.kauffman.org/items.cfm?itemID=678.

25 "Is China the next R&D superpower?" *Electronic Business*, 1 July 2005 http://www.reed-electronics.com/eb-mag/article/CA610433?pubdate=7/1%.

# Sector Benchmarks

Across many sectors of the economy, signs of trouble for the United States are showing up in areas important to national security, technological leadership and industrial capacity, showing the ripple effects of lapses in support for research and education.

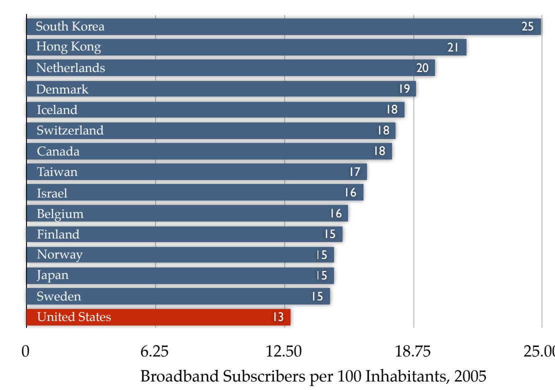
## *Information and Communications Technology*

The importance of information and communications technology (ICT) research in advancing the new economy is well documented. The resulting advances in these technologies have led to significant improvements in product design, development and distribution for American industry, enabled instant worldwide communication, improved health care delivery, enhanced our national security, and changed the conduct of research, enabling scientific discovery across every discipline. Staying at the leading edge of ICT technologies research is fundamental to U.S. competitiveness and security, especially as other countries invest heavily in ICT infrastructure and R&D. While the federal investment in ICT research will exceed $3 billion in FY 2007, the President's Information Technology Advisory Committee is concerned that the portfolio has become too short-term in focus, and that the long-term research necessary to ensure America's continued leadership in ICT is inadequately supported.[26]

- **Asia leads in list of top IT companies:** In the *BusinessWeek* rankings of the world's top Information Technology (IT) companies, 5 Asia-based companies are in the top 10 while only 1 is based in the United States. In the top 25, the United States improves to 8 companies, while Asia has 11.[27]

- **U.S. falls behind in broadband penetration:** The United States fell in the OECD broadband penetration rankings from 4th in 2001 to 12th in 2004.[28] For 2005, the International Telecommunications Union lists the United States as 15th, below such countries as Korea where nearly 1 of 4 inhabitants has broadband.

U.S. Lags Many Countries in Broadband Penetration




Source: International Telecommunication Union, November, 2005.

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26. President's Information Technology Advisory Committee, *Cyber Security: A Crisis of Prioritization*, Report to the President. February, 2005 and PITAC, *Computational Science: Ensuring America's Competitiveness*, Report to the President, June 2005.

27. "The Information Technology 100," Business Week, July 3, 2006, http://www.businessweek.com/magazine/toc/06_27/B399106it100.htm.

28. "OECD Broadband Statistics," Organisation for Economic Co-operation and Development, Dec. 2004. http://www.oecd.org/document/60/0,2340,en_2649_34225_2496764_1_1_1_1,00.html#Graph1.

## QUOTED

Since 1995, Information Technology industries have accounted for 25 percent of overall economic growth, while making up only 3 percent of the GDP. As a group, these industries contribute more to economy-wide productivity growth than all other industries combined.

- **Dale Jorgenson, Harvard Economist**, *Moore's Law and the Emergence of the New Economy*, Semiconductor Industry Association Annual Report, 2005. http://www.sia-online.org/downloads/SIA_AR_2005_Jorgenson.pdf

- **Patent indicators point to Asia:** North America accounted for 41 percent of the IT patents filed in the United States, while 59 percent were from Asia. IT companies constitute 17 percent of all patents filed in the United States.[29]

## TRENDS TO WATCH

**China overtakes U.S. as largest IT exporter:** A recent OECD document reports that "China has overtaken the United States as the world's biggest exporter of information technology goods." China achieved the top ranking with a 46-percent jump over its 2003 exports of information and communication technology, compared to the 12-percent U.S. increase. While most of China's high-tech exports come from plants in China owned by foreign companies, the shift in manufacturing will help build China's technological capabilities.[vi]

*vi.* "China overtakes U.S. as world's leading exporter of information technology goods," Organization for Economic Cooperation and Development, Dec. 12, 2005, http://www.oecd.org/document/60/0,2340,en_2649_201185_35834236_1_1_1_1,00.html.

29. "India, China could be big players in patent game," *CyberMedia India Online Limited*, April 3, 2006, http://www.ciol.com/content/search/showarticle1.asp?artid=82489.

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The semiconductor industry invests approximately 15 percent of sales into R&D. Even with these levels of investment, we are increasingly looking to universities for long-range research – challenges 5 to 15 years from today. Leadership in these areas will determine our future competitiveness.

- **Richard K. Templeton, President and CEO, Texas Instruments,** National Summit on Competitiveness, December 6, 2005

### *Semiconductors*

The semiconductor industry, which forms the core of the high-tech industry, churns out more U.S. patents than any other industry[30] and employed 223,000 individuals nationwide in 2005.[31] Further, seven of the top ten corporate U.S. patent recipients in 2004 are major semiconductor producers. Semiconductors are also the largest U.S. high-tech exporter, and 75 percent of U.S. chip industry sales are outside of the United States.[32]

- **DOD report warns of threats to semiconductor leadership and consequences to national security:** The Defense Science Board Task Force on High Performance Microchip Supply warns that the relocation of critical microelectronics manufacturing capabilities to other countries could pose significant national security and economic concerns. In addition, while the defense task force believes the United States is "still the leader in technology, and a sufficient supply of many trusted microelectronic components is available," it cautions that "trends of the last few years ... indicate that this will not continue in the near term unless direct action is taken in the immediate future."[33]

TRENDS TO WATCH

**Korean company has ambitious plans:** Samsung Electronics has announced that “it would spend $33 billion to build nine new chip lines in South Korea by 2012, creating 14,000 jobs,” placing it on a trajectory to become the world’s leading chip producer by that year.[vii]

*vii*. “Samsung to Invest $33 Billion in Making Chips,” *The New York Times*, Sept. 30, 2005.

30. “The Patent Scorecard,” ipIQ, 2006, http://www.ipiq.com/what_we_think/publication_detail.asp?publication_id=34.

31. Bureau of Labor Statistics, Department of Labor, http://data.bls.gov/PDQ/outside.jsp?survey=ce.

32. Semiconductor Industry Association and Choose to Compete, http://www.choosetocompete.org/us_chip_industry.html.

33. Defense Science Board, *High Performance Microchip Supply*, February 2005 http://www.acq.osd.mil/dsb/reports.htm.

- **Market share shows large Korean and Taiwanese growth:** Since the late 1990s, the U.S. owned companies have held about half of the worldwide semiconductor market, but witnessed a small but steady decline from 53 percent in 1998 to 48 percent in 2005. During this period, Taiwanese firms doubled their worldwide semiconductor market share from 3.3 percent to 6.5 percent; Korea increased from 6.9 percent to 10.5 percent; and Europe from 11.8 percent to 12.1 percent.[34]

- **U.S. leading-edge chip production capacity declined sharply:** The U.S.-owned capacity of leading-edge chip production declined from a 1999 high of 36.1 percent to 13.9 percent in 2005, a clear indication of how competitive the market for the newest generation of chips has become.[35]

34. "The Semiconductor Industry – an Important U.S. Industry and Patent Office Customer," Daryl Hatano, Semiconductor Industry Association, presentation to the U.S. Patent and Trademark Office, April 25, 2006.

35. Semiconductor Industry Association and Choose to Compete, http://www.choosetocompete.org/us_chip_industry.html.

## *Nanotechnology*

The National Science Foundation estimated in 2000 that the global impact of nanotech-enabled products will surpass $1 trillion by 2015. Since then, two groups have put the figure at $2 trillion or beyond.[36]

- **U.S. leads world in nanotechnology but competition is fierce:** Two recent reports, one by Lux Research[37] and one by the President's Council of Advisors on Science and Technology,[38] confirm that the United States leads the world in nanotechnology, but that future leadership is not assured.
  - Despite doubled spending on nanotechnology between 2001 and 2004, the U.S. share of the global investment in this field decreased from 30.3 percent to 26.2 percent.[39]
- **Other countries have made nanotechnology a priority:**
  - Taiwan, Japan and South Korea all had higher per-capita government spending on nanotechnology in 2004 than the United States.[40]
  - Japan and the E.U. spend nearly as much on nanotechnology as the United States. In 2004, government spending for nanotechnology R&D was $1.08 billion in the United States, $950 million in Japan and $1.05 billion in the E.U. Asia as a whole outspends the United States.
  - The Chinese government has made another promise to boost significantly its investment in the nanotechnology sector, focusing on fields such as microelectronics, medical materials and energy projects.[41] *People's Daily* reports that China led the world in nanotechnology research articles for the period of January 2004 to October 2004.[42]

## *Chemical Industry*

On top of about $1 billion in annual federal funding for chemical research, industry adds about $5 billion. Chemical companies realize $2 of operating income and a 17 percent return for every $1 invested in R&D. On this foundation, the overall U.S. chemical industry generates about $10 billion in operating incomes;

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36. Sean Murdock, Executive Director, NanoBusiness Alliance, Testimony before the Research Subcommittee of the House Science Committee, June 29, 2005; http://www.house.gov/science/hearings/research05/june29/Murdock.pdf.

37. *Nanotechnology: Where Does the U.S. Stand?* Lux Research, 2005.

38. *The National Nanotechnology Initiative at Five Years*, President's Council of Advisors on Science and Technology, May 2005. http://ostp.gov/pcast/PCASTreportFINAL.pdf.

39. Sean Murdock, Executive Director, NanoBusiness Alliance, Testimony before the Research Subcommittee of the House Science Committee, June 29, 2005; http://www.house.gov/science/hearings/research05/june29/Murdock.pdf.

40. *Nanotechnology: Where does the U.S. Stand?* Lux Research, New York, 2005.

41. "China backs future nanotech research," *SciDevNet*, June 17, 2005 http://www.scidev.net/content/news/eng/china-backs-future-nanotech-research.cfm.

42. "China tops the world in nano-papers," *People's Daily* Online, June 10, 2005 http://english.people.com.cn/200506/10/eng20050610_189642.html.

employs 600,000 people in high-skill, high-wage jobs; contributes $40 billion in value added toward the GDP; and pays $8 billion in taxes.[43] But there are warning signs for the future.

- **U.S. growth lags China and India:** The chemical industry, which generates nearly 12 percent of all U.S. patents and invests $22 billion in R&D, grew an average of 1.7 percent from 1998-2003. The rate in China was 13.4 percent and India 6.7 percent.[44]

- **Giving up on chemicals:** According to *BusinessWeek*, of 120 chemical plants being built around the world with price tags of $1 billion or more, one is in the United States and 50 in China. Further, 70 chemical facilities were closed in the United States in 2004 and 40 more are slated to be shut down.[45]

## *Defense and Aerospace Industry*

Maintaining the U.S. defense and aerospace industrial base is critical to both our national security and our economic health. Aerospace alone provides our nation's largest trade surplus ($37 billion in 2005),[46] as U.S. companies in this sector continue to invest heavily in R&D, spending more than $50 billion over the last 15 years. In 2006, the aerospace industry was responsible for over $270 billion in net domestic sales and accounted for 624,000 in total employment.[47]

- **Significant defense and aerospace retirements are expected over the next decade:** Nearly one-third of the civilian scientific and technical workforce in the Department of Defense (DOD) is currently eligible to retire.[48] This percentage is expected to more than double over the next seven years, with nearly 70 percent eligible to retire. Moreover, at least 13,000 DOD laboratory scientists are expected to retire within the next decade while over one quarter of the current aerospace workforce will be eligible to retire by 2008.[49]

- **Defense and aerospace industries and national security agencies must rely on U.S. citizens:** Unlike many sectors of the U.S. economy that have been increasingly able to rely on foreign talent to fill science and technology employment vacancies, U.S. citizens are needed to fill security-related positions in the defense industry, the military, the national laboratories, the Departments of Defense

43. Council on Chemical Research, *Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine*, 2005.

44. *Ibid*.

45. "No Longer The Lab Of The World," *Business Week*, May 2, 2005. http://www.businessweek.com/magazine/content/05_18/b3931106.htm.

46. "Encourage Revitalization of U.S. Aeronautics Research," Aerospace Industries Association, http://www.aia-aerospace.org/pdf/06issue_revitalization.pdf.

47. "Aerospace Statistics," Aerospace Industries Association, http://www.aia-aerospace.org/stats/aero_stats/stat12.pdf.

48. William Butz et al., "Will the Scientific and Technical Workforce Meet the Requirements of the Federal Government?" Rand Corporation, 2004, p. 41.

49. Department of Defense Research and Engineering, http://www.dod.mil/ddre/doc/NDEA_BRIEFING.pdf; Commission on the Future of the U.S. Aerospace Industry. "Final Report of the Commission on the Future of the United States Aerospace Industry," Nov. 18, 2002. http://ita.doc.gov/td/aerospace/aerospacecommission/aerospacecommission.htm.

and Homeland Security and the federal intelligence agencies. These employers are finding it increasingly difficult to find qualified U.S. scientists and engineers who can receive security clearances.

- **U.S. aerospace companies face government-sponsored foreign competition:** U.S. aviation manufacturers are faced with determined international competitors backed by their host governments. For example, the European Union's (E.U.) plan, Vision 2020, is designed to produce European leadership in all aspects of civil aviation by the year 2020. There is strong evidence that the E.U. aims to achieve that goal by implementing dynamic programs in areas such as aeronautics R&D. In space-launch and satellite manufacturing, for example, Europe, India and China all have state-supported companies that compete with U.S. firms. The increased commitment of other governments comes at the same time the U.S. government has been decreasing its commitments in this area. For example, NASA's out-year aeronautics R&D funding is projected to be flat or declining for the foreseeable future.[50]

- **Precipitous drop in DARPA support for computer science research:** DARPA's support for university-based computer science research has been cut in half in recent years because of recent policy decisions: classification of programs, prohibitions on the participation of foreign nationals and shorter research horizons. The result is that DARPA has significantly reduced its investments in university-based computer research and some of the best minds in the nation (if not the world) are no longer focused on DOD-relevant problems or on future computing technologies.[51]

- **Critical national security fields lack adequate support:** Specific areas of basic research critical to national security, such as cyber security research, are not receiving adequate government attention. The Department of Homeland Security is not investing a significant amount in this area, especially in long-term research. DARPA is investing, but it is classifying programs and thus greatly reducing its traditional reliance on university-based research in these areas. NSF supports high-quality efforts and the research is sufficiently long-term, but the program is only modestly funded relative to the number of excellent proposals. Consequently award rates are dismal — only 8.2 percent of proposals to NSF's Cyber Trust cyber security research program received funding in FY 2004.[52]

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50. "Encourage Revitalization of U.S. Aeronautics Research," Aerospace Industries Association, http://www.aia-aerospace.org/pdf/06issue_revitalization.pdf.

51. John Markoff, "Pentagon Redirects Its Research Dollars," *The New York Times*, April 2, 2005. http://www.nytimes.com/2005/04/02/technology/02darpa.html?ex=1270098000&en=e081c19247a119ed&ei=5090&partner=rssuserland; Joint Statement of the Computing Research Community, Hearing on the Future of Computer Science Research in the U.S, Science Committee, U.S. House of Representatives, May 12, 2005, http://www.cra.org/govaffairs/jointstatement_final.pdf); Barton Reppert, DARPA Assailed for Cutting Back Support of Basic Computing Research at U.S. Universities, *Today's Engineer*, June 2005, http://www.todaysengineer.org/2005/Jun/computing.asp.

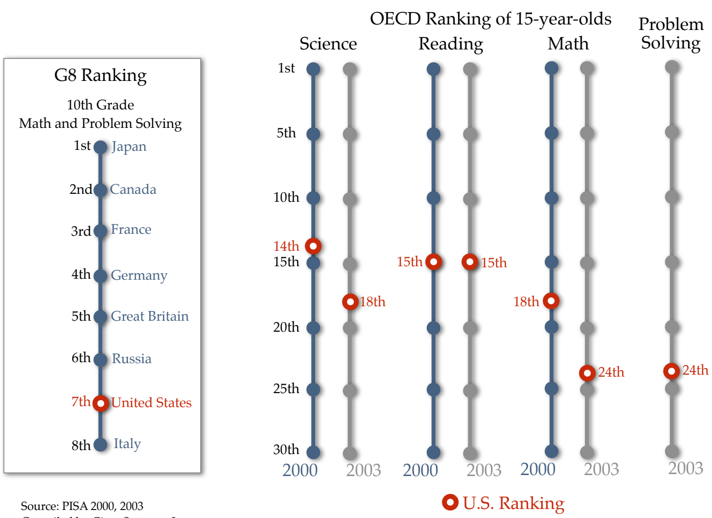
52. Presidents Information Technology Advisory Committee, *Cyber Security: A Crisis of Prioritization*, February 2005, http://www.nitrd.gov/pitac/reports/20050301_cybersecurity/cybersecurity.pdf); Danielle Belopotoski, "White House urged to make cybersecurity a priority," GovExec.com, Oct. 27, 2005, http://www.govexec.com/story_page.cfm?articleid=32680&printerfriendlyVers=1&.

# Education Benchmarks

The potential researchers of the future are in school today. But they are not getting the support and preparation they need to become the science and engineering leaders of tomorrow. We need our best and brightest students to get excited about science and math again, and devote their talent and energy to these fields that promise opportunity for them and for the country.

## *Elementary and Secondary Education*

U.S. Students Rank Poorly Compared to G8 and OECD Countries




Source: PISA 2000, 2003
Compiled by Cisco Systems, Inc.

- **U.S. teenagers lag most developed countries in math and science literacy:** In the 2003 OECD ranking of the mathematics and science performance of 15-year-olds in the 30 OECD countries, the United States ranked 18th and 24th, respectively, scoring below the OECD average for each. The rankings are similarly poor when the list is narrowed to the countries of the G8.[53] To quote the 2005 OECD report, Education at a Glance, "With its relatively high expenditure and its relatively low student achievements at the school level, the United States education system is clearly inefficient."

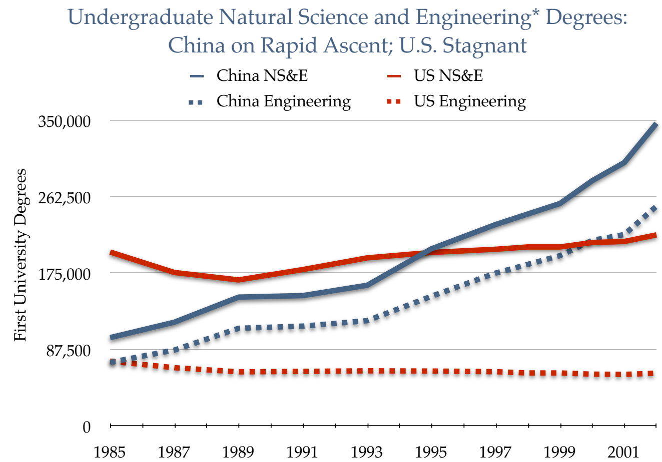
## *Undergraduate Education*

- **The United States falls behind in the ratio of undergraduate natural science and engineering (NS&E) degrees to broader populations:**
  - While U.S. NS&E degrees as a percentage of the population of U.S. 24-year-olds increased from 4 percent in 1975 to 5.7 percent in 2000, this country fell below the OECD average of roughly 6.8 percent. In 1975, only two countries had higher ratios than the United States. By 2000, 25 countries had higher ratios.[54]

53. *Learning for Tomorrow's World – First Results from PISA 2003*, Organisation for Economic Cooperation and Development Programme for International Student Assessment, Tables 2.5c and 6.6 http://www.pisa.oecd.org/document/55/0,2340,en_32252351_32236173_33917303_1_1_1_1,00.html.

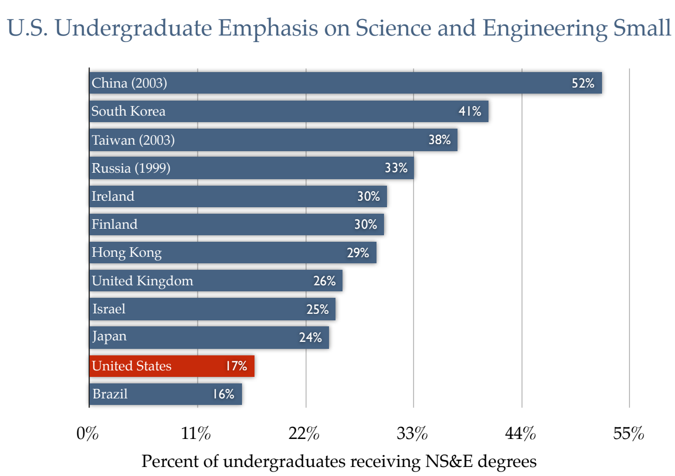
54. *2004 NSF Science and Engineering Indicators*, National Science Board, Figure O-20 and Appendix Table 2-33.

- A majority of countries rank higher than the United States in the ratio of NS&E degrees to all first university degrees. The U.S. ratio is just 16.8 percent, compared with the world average of 26.4 percent. Of the 42 countries that granted more than 20,000 university degrees in 2002 (or most recent year for which data is available), the United States is in the bottom quartile. A selection of countries is shown below.




* NS&E degrees include natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences, mathematics and engineering. Missing U.S. 1999 data approximated by 1998 data.
Compiled by the APS Washington Office.
Source: *2004* and *2006 Science and Engineering Indicators*, National Science Foundation

- **U.S. is less competitive in university computer programming contest:** For the second straight year, U.S. teams had mediocre performance in the world finals of the Association for Computing Machinery International Collegiate Programming Contest. In 2005 the highest U.S. finisher was 17th, the poorest U.S. showing in the 29-year history of the competition. The U. S. rebounded slightly in 2006 with a team finishing in 8th place. While four U.S. teams finished in the top 10 in 2004, the 2005 and 2006 results are consistent with a downward trend since the four U.S. wins in the early- and mid-1990s. Teams from Asia and the former Soviet Union countries now regularly win the competition.[55] On the other hand, "a list of where the world's 1,000 best computer scientists were educated shows that the top 10 schools were all American."[56]




*NS&E degrees include natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences, mathematics, and engineering. Data are for 2002 (or most recent year).
Source: *NSF Science and Engineering Indicators 2006.*
Compiled by the APS Washington Office.

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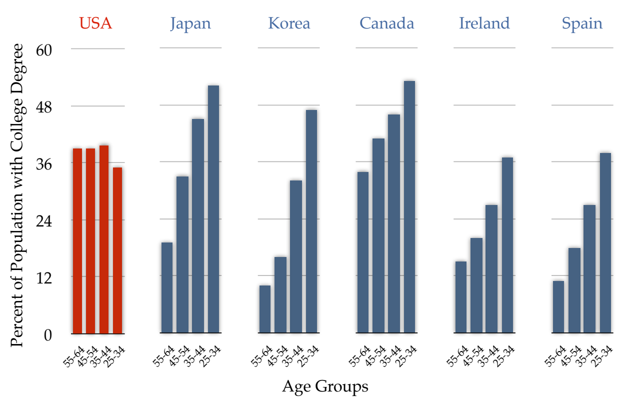
55. "U.S. slips lower in coding contest," CNET News.com, Apr. 7, 2005 http://news.com.com/U.S.+slips+lower+in+coding+contest/2100-1022_3-5659116.html?tag=nl and http://icpc.baylor.edu/past/default.htm.

56. Fareed Zakaria, "How Long Will America Lead the World?," *Newsweek*, June 12, 2006, http://www.msnbc.msn.com/id/13123358/site/newsweek.

- **U.S. undergraduates' emphasis on science shrinks:** In the broader category of science, technology, engineering and mathematics (STEM), a 2005 Government Accountability Office report shows that as college enrollment has increased from 1995 to 2004, the proportion of students obtaining degrees in STEM fields has fallen from 32 percent to 27 percent.[57]

- **U.S. falls from first to eighth in percentage of population receiving a college degree:** According to a recent OECD report on the percentage of various age populations receiving college and high school degrees, the United States is first in the 45-54 age group but only 8th in the 25-34 age group. Germany and the United States were the only two countries where the number fell for younger generations. The result is similar for high school diplomas.[58]

Other Countries Educating Higher Proportion of Younger Generations




Source: Education at a Glance, 2005, OECD.
Compiled by the APS Physics Washington Office

## SIGNS OF UNITED STATES LEADERSHIP

**U.S. universities are still best in the world:** In its rankings of the top universities in the world, researchers at the Shanghai Jiao Tong University found that the United States had 8 of the top 10 and 35 of the top 50.[viii] A report from the Center for European Reform found that the United States has 18 of the world's top 20 universities, and 37 of the top 50.[ix]

*viii.* "Academic Ranking of World Universities – 2004," Institute of Higher Education, Shanghai Jiao Tong University, 2004 http://ed.sjtu.edu.cn/ranking.htm.

*ix.* "The Future of European Universities," Center for European Reform, 2006 http://www.cer.org.uk.

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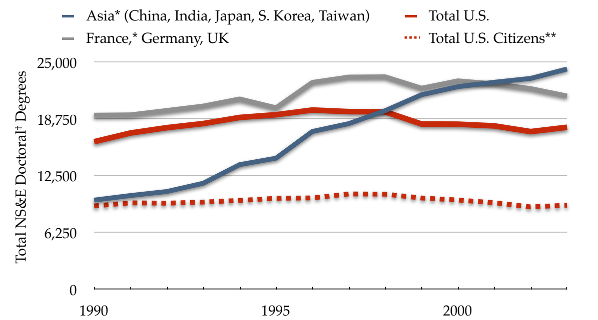
57. Cornelia Ashby, Director of Education, Workforce and Income Security Issues, U.S. Government Accountability Office, "Science, Technology, Engineering and Mathematics Trends, and the Role of Federal Programs", testimony before the House Committee on Education and the Workforce, May 3, 2006; http://www.gao.gov/new.items/d06702t.pdf.

58. "Education at a Glance: OECD Indicators 2005," OECD.

### *Graduate Education*

- **Asian production of natural science and engineering (NS&E) Ph.D.s is on a steep trajectory; U.S. figure stagnant:** The number of NS&E Ph.D.s granted in several Asian countries is climbing quickly and shows no sign of slowing. Their production surpassed the flat figure of the United States in 1998 and the gap has been quickly widening. Three European countries collectively have more than the United States but show a similar flat to declining trend in recent years.

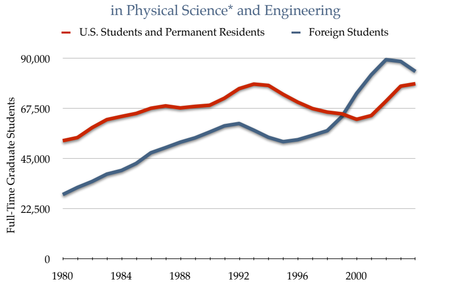
Asian Output of Ph.D.s on Rapid Rise, U.S. Number Flat, with Half Going to Foreigners




*Some data were not available. As a conservative estimate, most recent value was carried over. 2001 China data used for 2002 and 2003 values; 2001 Taiwan value for 2002 value; 2000 and 2002 South Korea data for 2001 and 2003, respectively; 1999 France value for 2000-20003. **U.S. Institutions only. †NS&E degrees include natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences, mathematics, and engineering.
Source: *2006 Science and Engineering Indicators*, National Science Foundation.
Compiled by the APS Washington Office.

- **Foreign students are a majority in many U.S. graduate schools:** Since 2000, there have been more foreign graduate students studying engineering and the physical, computer and mathematical sciences in U.S. graduate schools than U.S. citizens and permanent residents. The 2003 and 2004 data indicate that the gap has narrowed recently, which may have to do with post 9/11 visa restrictions and the dot com bubble burst. While the trend of increasing numbers of foreign graduate students is encouraging, the outnumbering of American students raises the concern of an over-dependence on foreign talent and suggests that we must increase our efforts to encourage more U.S. students to enter these fields.

U.S. Graduate Institutions: Foreign Students Outnumber U.S. Students in Physical Science* and Engineering




* Mathematical and Computer Science included.
Source: National Science Foundation Division of Science Resources Statistics: Graduate Students and Postdoctorates in Science and Engineering, Fall 2002, Fall 2003, and Fall 2004. Compiled by the APS Physics Washington Office.

## TRENDS TO WATCH

**China makes world-class research universities a priority**: China "has declared that transforming 100 universities into world-class research institutions is a national priority and is persuading top Chinese scholars to return home from American universities."[x] To support this bid to "transform its top universities into the world's best within a decade, … [China] is spending billions of dollars to woo big-name … foreign-trained Chinese and Chinese-American specialists."[xi]

*x*. "U.S. Slips in Attracting the World's Best Students," *The New York Times*, Dec. 21 2004.

*xi*. "China Luring Scholars to Make Universities Great," *The New York Times*, Oct. 28 2005.

# Workforce Benchmarks

***Attracting America's Brightest***

As reported in the previous section, U.S. student interest in science and math has waned so much since the Sputnik days that there are now fewer Americans studying science and engineering in U.S. graduate schools than foreigners. Luring America's young talent to science and engineering is essential to our future competitiveness, especially as more and more research and development opportunities develop in other parts of the world.

- **Science and math skills become more important to the U.S. workforce:** From 1994 to 2003, the proportion of the workforce working in STEM fields jumped from 17 percent to 23 percent.[59]

- **The U.S. is increasingly reliant on foreign talent to fulfill its science and engineering workforce needs:** In 2003, according to the National Science Foundation, 25 percent of all college-educated professionals in science and engineering occupations in the United States were occupied by foreign professionals, double the percentage in 1980. At the doctorate level, the share of foreign-born professionals increased from 24 percent to 38 percent between 1990 and 2000. During this same period, the percentage of foreign born Ph.D.s in the U.S. workforce under age 45 in these fields rose from 27 percent to over 52 percent. Indeed, almost 60 percent of the growth in Ph.D. scientists and engineers during this period came from foreign-born talent. This suggests that as the homegrown science and engineering talent generated by the Sputnik era retires, it is increasingly replaced by foreign-born talent.[60]

***Attracting the Best Talent from Around the World***

The United States is a great place to do technical work, and the world knows this. (See sidebox.) Yet, we can no longer count on the world's top technical talent coming to the U.S., and we are seeing these talented individuals return to their homelands. As David Heenan points out in his book, *Flight Capital*, more and more foreign-born Americans of all trades and professions are returning to their homeland. In 2005, the number reached up to 1,000 people a day. We need to reinvigorate the U.S. research enterprise to keep attracting the best talent from around the world and to keep this talent in the United States.

- **Foreign interest in U.S. graduate schools has declined:** The Council of Graduate Schools reports that applications to U.S. graduate schools fell by 28 percent between 2002-2003 and 2003-2004 and by another 5 percent between 2003-2004 and 2004-2005, before increasing by 11 percent between 2004-2005 and 2005-2006. Despite the latest increase, the number of international applications is down 23 percent

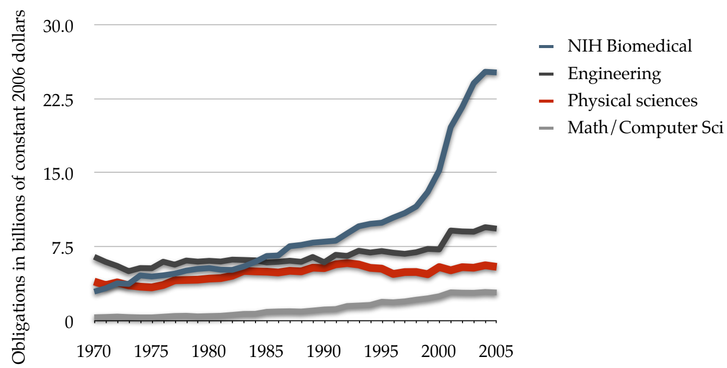
59. Cornelia Ashby, Director of Education, Workforce and Income Security Issues, U.S. Government Accountability Office, "Science, Technology, Engineering and Mathematics Trends, and the Role of Federal Programs," testimony before the House Committee on Education and the Workforce, May 3, 2006.

60. National Science Foundation, *Science and Engineering Indicators, 2004 & 2006*; Richard B. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership," NBER Working Paper No. 11457, June 2005.

since 2003 for responding institutions. New international enrollments fell for three consecutive years, before increasing by 1 percent in the fall of 2005.[61]

- **The United States is experiencing reverse brain drain:** Indian Americans, who constitute the top-earning ethnic group in the United States, are returning to India in great numbers. David Heenan estimates the number at 25,000 in a recent three-year period.[62] Nasscom, an Indian software industry organization, estimates that 30,000 technology professionals have returned from around the world in a recent 18-month period.[63]

Trends in Federal Research, by Discipline, 1970-2005




* Other includes research not classified. Includes basic research and applied research, excludes development and R&D facilities. Life sciences -- split into NIH support for biomedical research and all other agencies' support for life sciences.
Source: National Science Foundation, *Federal Funds for Research and Development, FY 2003, 2004, 2005, 2006*. FY 2005 and 2006 are preliminary. Constant dollar conversions based on OMB's GDP deflators for FY 2006.
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For Lockheed Martin, where almost half of our 135,000 employees are scientists and engineers, questions of technological competitiveness go to the heart of our ability to innovate and thrive. Given the security constraints surrounding our work, outsourcing and offshoring aren't feasible options for companies in our sector. For the aerospace and defense industry, the front lines of the brainpower battle aren't in China, they're here at home.

One in every three of Lockheed's employees is over 50. To sustain our talent base, we're hiring 14,000 people a year. In two years, we're going to need 29,000 new hires; in three years, 44,000. If this trend continues, over the next decade we will need 142,000. We're not alone; industry-wide, some 19 percent of employees are eligible for retirement. Yet Department of Education data suggests U.S. colleges and universities are only producing about 62,000 engineering B.A.'s a year — fewer than the visual and performing arts graduates — and that figure hasn't grown in a decade.

- **Robert J. Stevens, CEO, Lockheed Martin** in "Social Engineering," Op-ed, *The Wall Street Journal*, April 19, 2006.

61. Council on Graduate Schools, *Findings from the 2006 CGS International Graduate Admissions Survey, Phase I: Applications*, Mar. 2006, http://www.cgsnet.org/portals/0/pdf/R_intlapps06_1.pdf.

62 David Keenan, Radio West, Nov. 1, 2005. http://www.publicbroadcasting.net/kuer/news/news.newsmain?action=article&ARTICLE_ID=836814.

63. "Big Apple to Bangalore: Brain drain in reverse," *The Times of India*, Dec. 29, 2005.

- **Reverse recruiting — Singapore attracts world's top talent:** Singapore, seeking to become a major power in biomedical research, has lured thousands of researchers, many of them leaders in their field.[64] One estimate is that 70 percent of the Singapore Genome Institute's 170 faculty come from abroad.[65]

- **Foreign workers face many hurdles:**

  - Current limits on green cards, especially for professionals from high-demand countries like China, result in employees waiting for many years to obtain permanent residency. For example, a scientist from India or China would have had to apply in 2001 to be considered for a green card in 2006. Without permanent residency, these individuals are unable to seek promotions, move to a new city, or change jobs.[66]

  - The FY07 cap on H-1B visas — 65,000 — was reached in early June, nearly four months before the start of the fiscal year. The cap on H-1B visas for foreign nationals with advanced degrees from U.S. universities was reached in August, precluding employers from hiring this specialized professional talent for over a year.[67]

According to one calculation, 3,000 of the technology firms created in Silicon Valley since the 1980s — more than 30 percent of the total — were founded by entrepreneurs with Indian or Chinese roots. The science and engineering departments of America's leading universities have drawn the brightest graduate students from around the world. A great many have stayed and created wealth for themselves and the country where they chose to reside.

64. "Singapore's Regenerations: With an open Checkbook, the tiny city-state draws top scientists," *The Chronicle of Higher Education*, Nov. 11, 2005.

65. David Heenan, *Flight Capital: The Alarming Exodus of America's Best and Brightest*, (Davies-Black 2005), p. 6.

66. State Department Visa Bulletin, May 2006, http://travel.state.gov/visa/frvi/bulletin/bulletin_2868.html?css=print.

67. Compete America, http://www.CompeteAmerica.org.

# Conclusion

These benchmarks demonstrate America's historical strength in science and technology, but they also reveal the impact of earlier decisions about the federal investment in basic research in physics, mathematics, engineering, chemistry and computing. The benchmarks help us see how inadequate investment has helped to set in motion an erosion of American leadership in science, in turn jeopardizing the foundation upon which our future economic and national security will be built.

The benchmarks show growing international competition as well. Other nations, particularly in Asia, have learned from America that a strong science and technology sector provides for economic growth and national security. They are putting in place programs and investments to expand their scientific and technological capabilities with the intent of matching and eventually surpassing the United States. The growth of other nations is a welcome development — all the world benefits when any nation expands knowledge. But if the United States allows this expansion to challenge American leadership in innovation, the combination is likely to weaken this country.

As Rep. Frank Wolf (R-VA), a leading advocate of science and research, wrote last year: "America today finds herself at a crossroads when it comes to leading the world in science and innovation. We can continue down the current path, as other nations continue to narrow the gap, or we can take bold, dramatic steps to ensure U.S. economic leadership in the 21st century and a rising standard of living for all Americans."

Those who stand still will fall behind. The United States has been standing still in basic research in the physical sciences for more than a decade — a decade of immense change and rapid growth in the global economy. The Benchmarks show that if the United States continues to stand still, it faces inevitable decline. Avoiding this outcome does not require huge outlays of federal funds — the research funds in the American Competitive Initiative, if approved, involve only about one-tenth of one percent of federal discretionary spending — but it will require a new attitude and commitment toward sustained investment in basic research. With this commitment, we believe that the United States can continue to prosper and lead in this still-new century.

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# Endorsing Organizations

Association of American Universities 1900

USACM

ACS

AeA Advancing the Business of Technology

Agilent Technologies

American Institute of Physics 1931-2006 75 Years of Service

American Mathematical Society Founded 1888

APS physics

American Society for Engineering Education

ASTRA Alliance for Science & Technology Research in America

Battelle The Business of Innovation

Business-Higher Education Forum

Business Roundtable

Center for Accelerating Innovation

CompTIA

Council on Competitiveness

Computing Research Association CRA

EIA Electronic Industries Alliance

Google

IBM

intel

LUNA Innovations

Microsoft

NAM National Association of Manufacturers

National Association of State Universities and Land-Grant Colleges

Northrop Grumman

RTI International

The Science Coalition

SIA Semiconductor Industry Association

SURA Southeastern Universities Research Association

Texas Instruments

TIA